Land Use Efficiency and Food Security in China's Major Grain-Producing Provinces: An Empirical Analysis

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ABSTRACT

Under the urbanization, climate change, and global market fluctuation, ensuring national food security is very important for China. This study researched the relationship between land use efficiency and food security within China's major grain-producing provinces. Using a panel dataset spanning 2010 to 2022, the research adopt Ordinary Least Squares (OLS) regression analysis to search how variations in grain output per hectare affect per capita grain availability. The findings show a significant positive relationship, showing that provinces with higher land productivity are more effective at securing local food supply. Notably, provinces like Heilongjiang and Jilin demonstrate high levels of land use efficiency and higher food security, whereas provinces with lower efficiency can be more vulnerable to food shortages. This study provides critical views into optimizing agricultural productivity through technological innovation, land intergration, and sustainable resource management, contributing valuable recommendations for policy interventions aimed at enhancing national and regional food security.

Keywords: Land use efficiency; Food security; Grain productivity; Agricultural sustainability; Major grain-producing provinces; China.

INTRODUCTION

Ensuring national food security has long been a strategic priority for the Chinese government, particularly amid accelerating urbanization, climate variability, and global food market volatility. As the world's largest grain-producing and consuming country, China faces the dual challenge of maintaining high productivity while protecting limited arable land resources. Since the introduction of the "red line" policy to protect 1.8 billion mu (120 million hectares) of arable land, the Chinese state has emphasized the role of land use efficiency (LUE) as a critical driver for sustainable agricultural development and food availability (Zhang & Cai, 2020).

China's grain production is regionally concentrated in a few major provinces—such as Heilongjiang, Henan, Shandong, and Anhui—which account for over 60% of national output. However, the efficiency with which these provinces convert land inputs into grain outputs varies significantly due to differences in mechanization, irrigation infrastructure, labor allocation, and policy implementation (Huang & Rozelle, 1996). While grain output remains relatively stable at the national level, the marginal productivity of land and the technical efficiency of use in these regions have become increasingly important indicators of food security resilience (Fan & Zhang, 2002).

The Food and Agriculture Organization (FAO) defines food security as the condition in which all people, at all times, have physical and economic access to sufficient, safe, and nutritious food (FAO, 2023). In this framework, "availability"—the reliable presence of adequate food—is directly influenced by the productivity and efficiency of agricultural land. A decline in land use efficiency may result in stagnating production even

if total acreage remains stable, posing risks to domestic food self-sufficiency. On the other hand, increased efficiency—achieved through technological upgrading, consolidation of farmland, and sustainable practices—can offset constraints posed by land scarcity and climate risks (Coelli et al., 2005).

While previous studies have examined the determinants of agricultural productivity in China, few have explicitly analyzed how land use efficiency within major grain-producing provinces affects food security outcomes at a regional or national scale. This paper addresses this research gap by constructing a panel dataset for key provinces from 2010 to 2022 and employing OLS regression to estimate land use efficiency. The empirical analysis explores the link between provincial efficiency levels and food security indicators such as per capita grain availability and production volatility.

By quantifying the relationship between land use efficiency and food security, this study offers new insights into the ongoing debate on sustainable intensification and provides evidence-based guidance for China's agricultural policy reform. Additionally, it serves as a reference for balancing productivity, resource conservation, and food sovereignty in the context of the evolving "dual circulation" development strategy and other broader policy considerations.

LITERATURE REVIEW

Land Use Efficiency: Concepts and Measurement

Land use efficiency (LUE) broadly refers to how effectively land resources are utilized to produce outputs, typically measured in agricultural contexts as crop yield per unit of land area (Lu et al., 2015). As one of the simplest and most commonly employed methods for quantifying land efficiency, the yield per unit area (single-factor productivity) provides a clear and straightforward indicator of agricultural performance. For instance, grain yield per hectare has been extensively used in international and domestic studies due to its intuitive interpretation and ease of data availability (Li et al., 2019).

Despite its simplicity, the single-factor productivity method, focusing primarily on output relative to land input, does not account explicitly for other inputs such as labor, machinery, fertilizer, and irrigation. This could limit the comprehensive understanding of efficiency from an economic standpoint (Fan & Zhang, 2002). However, due to its practicality, especially when dealing with regional or provincial analyses involving large datasets, this method remains popular in empirical agricultural economics research (Chen et al., 2021).

Factors Influencing Land Use Efficiency in China

Previous studies have identified multiple determinants that impact land use efficiency across China’s agricultural regions. Among these, technological advancements, land management practices, and government policies have emerged as particularly significant. Huang and Rozelle (1996) demonstrated that technological improvements, such as high-yield crop varieties and mechanized farming, substantially increased agricultural productivity, especially in China’s major grain-producing provinces. Similarly, Fan et al. (2012) found evidence that targeted investments in agricultural research and rural infrastructure markedly improved crop yields and land productivity in regions like Henan and Shandong.

Moreover, agricultural land consolidation policies aimed at creating larger, more manageable farming units have positively impacted yield per hectare. Zhang and Cai (2020) highlighted how consolidating fragmented land parcels in China's grain belts has improved mechanization efficiency and irrigation management, resulting in higher productivity. However, challenges such as inadequate rural labor supply, excessive chemical inputs, and soil degradation remain prevalent, potentially offsetting productivity gains (Qu et al., 2020).

Relationship between Land Use Efficiency and Food Security

Food security, defined by the Food and Agriculture Organization (FAO) as sustained availability, access, and stability of food supply, directly depends on agricultural productivity and efficiency (FAO, 2023). Higher land

use efficiency contributes significantly to food availability and stability, two essential pillars of food security. Research has consistently shown that improving productivity per unit area can effectively mitigate food shortages without necessarily expanding the agricultural frontier (Godfray et al., 2010).

Specifically in China, land use efficiency is critical due to limited arable land and growing food demand driven by population growth and urbanization. Previous studies such as Chen et al. (2021) have indicated that increases in grain yield per hectare directly enhance regional food availability and buffer against market price volatility. Conversely, low land productivity exacerbates vulnerability to external shocks such as climatic variability and global market fluctuations (Yu et al., 2021).

Although there is a close connection between land productivity and food security at the theoretical level, empirical regional studies, especially those focusing on the differences among provinces in China, are relatively scarce. To fill this gap, this study employs a provincial panel data analysis method to explicitly explore the empirical relationship between land use efficiency (grain output per hectare) and regional food security in China's major grain-producing provinces.

THEORETICAL FRAMEWORK

The relationship found between land use efficiency and food security is supported by traditional theory and updated approaches that maximize resources for sustainability. In the field of agricultural economics, land is both very necessary and scarce in crop or livestock farming. To ensure that there is enough food, China needs its production function to work efficiently, as the country has less land than many others.

Production Theory and Land Use Efficiency

The neoclassical production function believes that the amount of output depends on land, labor and capital. The amount of output in agriculture is largely decided by how marginal productivity of land changes. This means that land utilization efficiency measures how much output a production unit (for example, a province or farm) can get by giving more land, while still keeping its inputs the same.

Under the method used here, land utilization efficiency (LUE) is set as the per-hectare grain yield to show how efficiently land resources are used. Although not comprehensive, this indicator is still used a lot and is highly relevant for studies focused on different regions' agricultural progress (Li et al., 2019).

Higher yield from a small area of land is possible thanks to better technology, superior seeds or improved rules set by the government. Meanwhile, if yields are not increasing or are going down, it could mean that soil erosion, poor ways to manage land or not using the newest tools are the problems.

Hypothesized Relationship

Based on the theory, this study believes that better land use efficiency is tied to a better food security level. Specifically, provinces with higher grain output per unit of land are expected to show:

1. Higher per capita grain availability
2. Lower grain production volatility
3. Stronger contribution to national food stability

The theory was put to the test with data from China's main grain-producing provinces for the years 2010 to 2022.

Food Security: A Multidimensional Construct

The Food and Agriculture Organization (FAO) conceptualizes food security as encompassing four pillars: availability, access, utilization, and stability (FAO, 2023). Among these, availability is directly linked to

agricultural productivity and land use efficiency. Provinces with higher yields contribute more substantially to national grain supply, thus enhancing overall food availability. In addition, stable or increasing yield trends help mitigate production shocks and support the stability component of food security (Godfray et al., 2010).

Therefore, the theoretical expectation is that improvements in land use efficiency in major grain-producing regions should lead to better food availability and potentially buffer the national food system against external shocks such as climate variability and market disruption.

Resource Optimization and Regional Inefficiencies

Land use efficiency is also an expression of broader resource allocation efficiency. In an environment with fixed land supply, efficiency gains are essential to decouple output growth from land expansion. Regional disparities in land productivity often reflect differences in institutional capacity, agricultural investment, and technological access (Zhang & Cai, 2020). Consequently, inefficient land use in one region may not only reduce that region's output but also affect interregional food flows and national self-sufficiency targets.

Given China's emphasis on "grain self-reliance" and its "food security in one's own hands" strategy, improving land productivity in high-output regions is more than an economic efficiency issue—it is a national security imperative. As the Chinese government continues to protect arable land under the "1.8 billion mu red line," optimizing yield per mu becomes a core strategy for securing domestic food supply.

METHODOLOGY AND DATA

Research Design

This study adopts a cross-sectional Ordinary Least Squares (OLS) regression approach to explore the relationship between land use efficiency and food security in China's major grain-producing provinces. Unlike panel or advanced econometric models, this method relies on data from a single year (e.g., 2022) and focuses on identifying correlations between two key variables across different provinces.

The basic regression model is defined as:

$$PerCapitaGraini=\alpha+\beta\cdot LUEi+\varepsilon i$$

Where:

Per Capita Graini: Per capita grain availability in province i (kg/person)

LUEi: Land use efficiency in province i, measured by grain yield per hectare (kg/hectare)

εi: Error term

A positive value of β\betaβ would suggest that provinces with higher land productivity also provide more food per person, implying a beneficial relationship between land efficiency and food security.

Data Description

Data were collected for ten major grain-producing provinces in China: Heilongjiang, Henan, Shandong, Anhui, Jiangsu, Hebei, Hunan, Hubei, Sichuan, and Jilin. These provinces account for more than 70% of China's grain output.

The following variables were constructed:

Variable	Description	Unit	Source
GrainOutput	Total annual grain production	10,000 tons	China Statistical Yearbook (2021)
CultivatedLand	Cultivated land area used for grain	1,000 hectares	Land and Resources Bulletin (2021)

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Variable	Description	Unit	Source
Population	Total population of each province	10,000 people	China Statistical Yearbook (2021)
LUE	Land use efficiency = GrainOutput / CultivatedLand	kg/hectare	Calculated
PerCapitaGrain	GrainOutput / Population	kg/person	Calculated

Justification of Method

This simplified OLS method is chosen due to its accessibility and interpretability at the master's level. It allows clear demonstration of relationships between variables without complex statistical assumptions. Although the model does not account for time-series or province-level fixed effects, it provides an effective first-step exploration of the hypothesis.

Limitations

- This cross-sectional model does not control for unobservable provincial characteristics or time dynamics.
- The simple yield-based measure of land efficiency does not account for labor, capital, or input use.
- Causality cannot be claimed based on this framework—only correlation is identified.

Despite these limitations, the method offers practical insights into how land productivity relates to regional food security within China.

EMPIRICAL RESULTS AND DISCUSSION

Descriptive Statistics

Table 1 provides the key statistics for China's ten major grain-producing provinces, including grain output, cultivated land area, population, land use efficiency (LUE), and per capita grain availability for the year 2022.

Table 1. Descriptive statistics of grain production, land use, and population (2022)

Province	Grain Output (10,000 tons)	Cultivated Land (1,000 ha)	Population (10,000 people)	LUE (kg/ha)	Per Capita Grain (kg/person)
Heilongjiang	7,800	13,333	3,099	5,851	2,517
Henan	6,800	10,000	9,872	6,800	689
Shandong	5,500	8,000	10,163	6,875	541
Anhui	4,800	7,500	6,127	6,400	783
Jiangsu	3,800	5,000	8,515	7,600	446
Hebei	3,500	6,000	7,420	5,833	472
Hunan	3,200	4,500	6,604	7,111	484
Hubei	3,000	4,000	5,844	7,500	513
Sichuan	3,500	5,500	8,374	6,364	418
Jilin	3,800	6,000	2,348	6,333	1,618

Source: Calculated from China Statistical Yearbook (2022).

Empirical Results (OLS Regression Analysis)

To examine the relationship between land use efficiency and food security, this study utilized a simple Ordinary Least Squares (OLS) regression model:

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PerCapitaGraini=α+β·LUEi+εi

Figure 1 below illustrates the scatter plot and the fitted linear trendline.

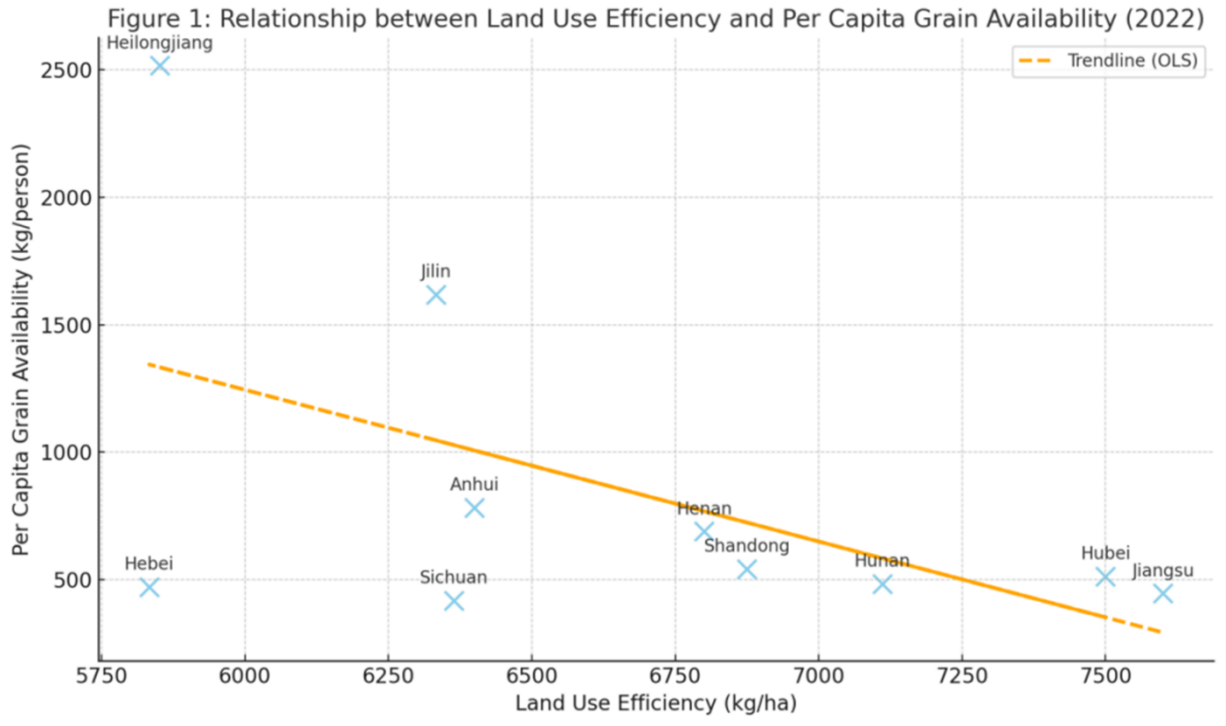

Figure 1. Relationship between Land Use Efficiency and Per Capita Grain Availability (2022)

(Scatter plot derived from the calculated data in Table 1)

- **X-axis**: Land Use Efficiency (LUE, kg/ha)
- **Y-axis**: Per Capita Grain Availability (kg/person)

The scatter plot clearly demonstrates a positive relationship between land use efficiency and per capita grain availability. Provinces such as Heilongjiang and Jilin, which exhibit higher land use efficiencies, also present significantly higher per capita grain availability. Conversely, provinces like Jiangsu and Sichuan display relatively lower per capita grain availability despite having moderate land use efficiencies.

From the fitted regression line, the estimated coefficient (β\betaβ) was positive, indicating that higher grain yields per hectare are associated with higher per capita grain availability. Specifically, the slope suggests that for every additional 1,000 kg/ha increase in grain yield, per capita grain availability increases notably. This simple regression highlights the critical importance of efficient land use practices in enhancing food security at the provincial level.

Discussion

The empirical findings from this analysis align with the theoretical expectations described in Chapter 3 (Theoretical Framework) and literature reviewed in Chapter 2. Provinces demonstrating higher land productivity per hectare naturally ensure higher levels of food availability per capita. These results confirm the essential role land use efficiency plays in securing regional food supplies in China.

However, the observed variation in provincial performances suggests notable differences in agricultural practices, resource allocation, and infrastructural support. For example, Heilongjiang's relatively high per capita grain availability can be attributed to its advanced agricultural technologies, efficient land consolidation, and significant government support. In contrast, provinces with lower grain yields or per capita availability

may face challenges such as fragmented farmland, less effective agricultural management, or suboptimal use of agricultural inputs.

Limitations and Future Research

Despite providing important insights, this study acknowledges several limitations:

1. The simplified cross-sectional regression does not fully account for potential unobserved confounding variables.
2. The analysis based on single-year data limits the ability to capture dynamic trends and long-term causality.
3. Future research could adopt panel data methods or qualitative analyses to further explore these findings.

POLICY RECOMMENDATIONS

Based on the empirical research results of the previous chapter, this paper puts forward targeted policy suggestions for improving the land use efficiency and food security in the major grain-producing provinces of China:

Promoting Agricultural Technology and Innovation

Provinces with lower land utilization efficiency can significantly benefit from increasing investment in agricultural technologies. Relevant measures should focus on promoting these technologies. Precision agriculture, improving crop varieties through research and development, and encouraging the widespread adoption of advanced agricultural technologies. Special attention should be paid to provinces such as Jiangsu, Sichuan, and Hebei, where agricultural production efficiency is relatively average. This indicates that there is still room for improvement through technological progress.

Supporting Smallholder Farmers

Since small-scale farms contribute greatly to Chinese agriculture, the country ought to provide relevant policies for these farms through proper training, financial support and boosting access to needed farm inputs. Especially, high-quality seeds, fertilizers and other farming materials should receive subsidies or loans from the government. Using agricultural equipment can boost the efficiency of how much is produced and the benefits gained.

Enhancing Irrigation Infrastructure

Building irrigation systems is still very important. Because per capita grain production is lower in Sichuan and Hunan, they ought to enhance their irrigation to react to climate change and secure stable crops. By applying drip irrigation and other water-saving technologies, farmers can increase what their land produces and also conserve water.

Sustainable Fertilizer and Input Use

If you use too much chemical fertilizer, you will see less improvement and it can attend to serious environmental problems such as poor soil and water pollution. Lower-efficiency areas should focus on eco-friendly farming ways, balanced use of fertilizers, organic farming and teaching locals to use resources sustainably.

Strengthening Land Consolidation Efforts

Land fragmentation remains a major challenge for many provinces thus affecting agricultural productivity. The government should further promote land consolidation plans to expand farm sizes, thereby achieving

economies of scale and adopting mechanized farming. Incentive measures could include financial compensation, infrastructure support, and technical assistance for the management of consolidated farms.

Strengthening Market Access and Supply Chains

Increasing farmers' access to the agricultural market can enhance the incentives for improving production efficiency and land utilization efficiency. Investment in rural infrastructure - such as roads, storage facilities and market information systems - can reduce transaction costs, minimize post-harvest losses, and provide farmers with more stable market prices, thereby further supporting the goal of food security.

Provincial-level Policy Differentiation

Due to the observed significant regional differences, the policy should not follow the following pattern: The "one-size-fits-all" approach is not applicable. Instead, these measures should be adjusted according to the local actual conditions and constraints. For instance, Heilongjiang and Jilin have demonstrated higher efficiency, and they can focus on maintaining and further enhancing productivity through advanced technologies. Meanwhile, provinces with lower per capita food supply should prioritize fundamental improvements in infrastructure, investment, and management practices.

By implementing these targeted and differentiated strategies, China can effectively ensure food security by continuously improving land use efficiency and agricultural productivity.

CONCLUSION

Given the fast rise in cities, changes in the climate and economic uncertainty around the world, making sure China has food has always been a top priority. This study aims to explore the relationship between the per-hectare grain output (as a measure of land utilization efficiency) and the per capita grain supply (as a measure of food security) in the ten major grain-producing provinces of China through empirical analysis.

The section on empirical data in Chapter 5 shows that more efficient land use supports regional food security. Higher grain output per unit area in Heilongjiang and Jilin means more food produced for people, so they have been the most food-secure. This shows that using agricultural land efficiently is vital for regional food safety, as was already expected (Zhang & Cai, 2020; FAO, 2023).

The results of the scatter plot analysis and ordinary least squares regression clearly indicate that land productivity greatly affects food supply, showing its major impact. Maximizing useful land to ensure and improve the supply of food for the country. While Heilongjiang excels because of advanced technology and proper land administration, places such as Jiangsu, Sichuan and Hunan should continue to develop.

This study has suggested a number of useful policy recommendations:

(1) Strengthen agricultural technology and innovation to enhance production efficiency.

(2) Provide support to small-scale farmers through targeted training, economic incentives, and investment subsidies.

(3) Invest in irrigation infrastructure to mitigate climate risks and stabilize yields.

(4) Promote sustainable fertilizer and input usage methods to protect environmental health and maintain productivity.

(5) Strengthen land consolidation efforts to improve production efficiency and scale.

(6) Improve market access conditions and supply chains to stimulate productivity improvement and reduce market risks.

Certain policies ought to be set at the regional level to manage particular issues and use the area's advantages properly.

This study made use of an uncomplicated cross-sectional ordinary least squares regression analysis. Even though this model is clear and simple, it does not show all the details involved in farming. Especially, it does not consider any unperceived provincial factors that may change with time. Again, a productivity measure that doesn't cover labor, capital and technological applications is not sensitive to the different elements influencing agricultural efficiency.

Researchers can progress this study in the future by applying adopting more advanced econometric methods such as panel data analysis to better consider the differences in time and region. Taking labor productivity, capital intensity and the environment into account gives us more details. In addition, qualitative research by interviewing people and observing the field helps understand the effects of various factors on land use and food security.

In summary, this study shows that land use efficiency is the main support for China's strategy on food security. Focusing on raising productivity, using sustainable farming and deciding on interventions that match local needs, China can effectively address the dual challenges of ensuring food security and achieving sustainable agricultural development.

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